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Applicant(s): Colvin, Butler, Korniski

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Title: PORTABLE VEHICLE EXHAUST FLOW SENSOR

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Date



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APPEAL BRIEF UNDER 37 C.F.R. §41.37

Appellants submit this revised Appeal Brief in response to the Notice of Non-Compliant Brief mailed 02/23/2007 providing a 30 Day Response Period.

Applicants appreciate the opportunity to address the issues identified in that notice. Applicants note that this application was filed using the old "EFS" system and does not have printed page and line numbers, so Applicants refer to paragraph numbers in lieu thereof.

This Brief is filed in support of the Notice of Appeal filed May 14, 2006. A decision on Applicants' Request for Pre-Appeal Brief Review indicating issues remained for consideration by the Board of Appeals was mailed on June 22, 2006.

Applicants are appealing the final rejection of claims 1-35 under 35 USC §§102(b), 103(a) for consideration by the Board of Patent Appeals and Interferences and request the final rejection of claims 1-35 be reversed and this case be remanded with instructions for passing to issuance.

(i) REAL PARTY IN INTEREST

The real party in interest for this application is the assignee, Ford Global Technologies, LLC., a Delaware limited liability company and wholly owned subsidiary of Ford Motor Company.

(ii) RELATED APPEALS AND INTERFERENCES

There are no prior or pending appeals, interferences or judicial proceedings known to appellant or the assignee that are related to, may directly affect, may be directly affected by, or may have a bearing on the Board's decision in the pending appeal.

(iii) STATUS OF CLAIMS

Claims 1-35 are currently pending in this application. Claims 1, 12-21, 23-27, and 32 have been rejected under 35 USC §102(b). Claims 4, 7, 8, 22, 29-31, and 35 have been rejected under 35 USC §103(a). Claims 2, 3, 5, 6, 9-11, 28, 33, and 34 were objected to as depending from a rejected base claim, but otherwise indicated allowable. All rejected claims are being appealed.

(iv) STATUS OF AMENDMENTS

A telephonic interview was held and an amendment after final was filed but has not been entered because the Examiner indicated it raised issues that require a new search of the prior art.

(v) SUMMARY OF CLAIMED SUBJECT MATTER

Applicants' invention as claimed in independent claims 1, 15, and 32 is directed to an on-board vehicle exhaust flow sensor that uses a screen to create a pressure differential. The claimed features that are in contention in this appeal include: Claim 1- "measuring a pressure difference upstream and downstream of

a screen" and "determining the exhaust gas flow based on the pressure difference and the temperature"; Claim 15 - "a tube adapted for placement on an exhaust pipe of the vehicle" that includes "a flow restricting element extending substantially entirely across a cross-sectional area of the tube" in addition to a "device in communication with the tube for determining the exhaust gas flow based on a difference between pressures upstream and downstream of the flow restricting element"; and Claim 32 - "a straight tube for connecting to an exhaust pipe of the vehicle" that includes "an interior screen to generate a pressure drop".

As illustrated in Figure 1, a prototype device 20 incorporating the invention includes a straight tube 22 (claim 15) adapted for coupling on the end of a vehicle exhaust pipe 24 for on-board exhaust flow measurement. [Para 21] As shown in Figures 2 and 3, the device includes a flow restriction element 92, 172 that is disk-shaped [Para 25] and extends substantially across a cross-sectional area of the tube or pipe 80, 150 [Para 27, 31, 32] as claimed in Claim 15. The flow restriction element 92, 172 includes regularly spaced openings [Para 27, 28] and may be implemented by a screen [Para 27, 28] as claimed in Claims 1 and 32. The open area is selected to reduce or minimize condensation on the flow restriction element and to minimize added back pressure in the exhaust system while still providing a measurable pressure differential. The measured pressure differential is then used to determine the exhaust flow [Para 28].

The flow restriction element that extends substantially entirely across the cross-sectional area as recited in claim 15 (and claim 12), or the screen 92, 172 as recited in claims 1 and 32 provide advantages and are distinguished over Laminar Flow Element (LFE) known in the prior art [Para 3, 7, 28, 52]. Example dimensions for Applicants' screen or flow restricting element are described with respect to Figure 2 [Para 28]. In Applicants' example, a six mesh (strands per inch) screen (Claims 14, 21) constructed of stainless steel wire (Claim 20) having a diameter of 0.035 inches (0.889 mm) and openings of 0.1317 inches (3.345 mm) was used to provide an opening or flow area of 62.7% of the cross-sectional area of tube 80. The relatively thin flow restriction element implemented by a screen resulted in an increase of back pressure of

approximately 5.2% which is within the range of normal barometric pressure variation. In addition, formation of condensation was reduced or eliminated so that it did not adversely affect the accuracy of flow measurements. For a typical automotive application, a screen mesh of ten or less is preferred to provide a flow area or spacing of between 60 and 65% of the cross-sectional area of the tube.

{Para 28]

Applicants' claimed invention provides a number of advantages relative to an LFE or hot-wire anemometer. For example, the circular flow restricting element of Applicants' claimed invention includes sufficient spaces to resist formation of condensation and minimize added back pressure while providing an accurately measurable pressure drop for a wide range of flows. Use of a thin screen or similar flow restriction element does not significantly increase the thermal capacity of the system and facilitates portability compared to conventional laminar flow measurement devices.

(vi) GROUNDS OF REJECTION TO BE REVIEWED

Claims 1, 12-21, 23-27, and 32 stand rejected under 35 USC §102(b) as being anticipated by Weigand (US 5,837,903). Dependent claims 4, 7, 8, 22, 29-31, and 35 stand rejected under 35 USC §103(a) as being unpatentable over Weigand (US 5,837,903),

(vii) ARGUMENT

REJECTION UNDER 35 USC §102(b)

Does the Linear Flow Element disclosed by Weigand '903 anticipate a screen as disclosed and claimed by Applicants?

The Examiner relies on US 5,837,903 to Weigand in rejecting Applicants claims stating that Weigand discloses measuring a pressure difference across a screen (18) as disclosed and claimed by Applicants. Applicants respectfully disagree. Weigand teaches use of a ceramic laminar flow element (LFE) (18) placed within the exhaust stream to create the pressure difference, not a screen as disclosed and claimed by Applicants. As described in Paragraph [0003] of Applicants' disclosure "laminar flow devices are typically too heavy for portable

use on a vehicle without additional reinforcement, contribute undesirable thermal capacity to the system, and do not have the desired operating range for use as a portable on-board measuring device. Formation of condensation on the flow measuring devices, especially during cold starts, may also result in measurement errors." As described in Paragraph [0007] of Applicants' disclosure, "use of a thin screen or similar flow restriction element does not significantly increase the thermal capacity of the system and facilitates portability compared to conventional laminar flow measurement devices" such as the ceramic LFE (18) disclosed by Weigand.

The use of a screen according to Applicants' invention also reduces or eliminates condensation that may adversely impact flow measurements. As described in Paragraph [0027] "screen 92 or other flow restriction element is preferably a circular element that extends across a cross-sectional area of tube 80 and includes a plurality of strands or wires arranged in an array with the spacing selected to reduce or eliminate formation of condensation under normal operating conditions, while providing a measurable differential pressure for exhaust flows ranging from engine idle to full throttle." Paragraph [0028] of Applicants' disclosure further describes and quantifies these advantages with reference to one embodiment where: "The relatively thin flow restriction element implemented by a screen resulted in an increase of back pressure of approximately 5.2% which is within the range of normal barometric pressure variation. In addition, formation of condensation was reduced or eliminated so that it did not adversely affect the accuracy of flow measurements."

Applicants' disclosure clearly distinguishes a screen from a conventional ceramic LFE as disclosed by Weigand, which has a considerable longitudinal dimension (with associated weight that makes it generally unsuitable for on-vehicle applications) required to create a laminar flow as known by those of ordinary skill in the art and illustrated in Fig. 1 of Weigand. As described by Applicants, the flow restricting element or screen is formed from a plurality of strands or wires arranged in an array with the spacing selected to reduce or eliminate formation of condensation under normal operating conditions, while providing a measurable differential pressure for exhaust flows ranging from engine idle to full throttle and to minimize increased back pressure. The

thickness or longitudinal dimension is relatively thin and based on the screen pattern and size of the wires or strands, which is on the order of 0.035 inches in one embodiment as described in Paragraph [0027]. Furthermore, LFE (18) clearly does not extend across the cross-sectional area (substantially or otherwise) of cylindrical body 12.

In contrast to the Examiner's contention, as shown in Fig. 1 of Weigand, LFE (18) is positioned in the center of cylindrical body 12 and covers only about 50-60% of the cross-sectional area. If LFE (18) extended substantially entirely across the cross-sectional area as disclosed and claimed by Applicants, the resulting back pressure would be significantly higher and likely unacceptable for many applications.

The longitudinal dimension of LFE (18) would also result in formation of condensation as evidenced by Weigand's use of a heating element (28) to heat body 12 and LFE (18) to maintain a temperature above the dew point of the exhaust gas to prevent formation of condensation. (See Col. 2, ll. 50-55; Col. 4, ll. 19-38; Col. 7, ll. 60-66; Fig. 7, block 148). "This preheating is necessary to prevent the thermal inertia of the ceramic laminar flowmeter from condensing exhaust gas water which will plug and occlude the capillary tubes of the capillary section and result in inaccurate readings." (Col. 9, ll. 55-58) As described above, Applicants' use of a relatively thin flow restricting element, such as a screen, does not require a heater to reduce or eliminate condensation, does not significantly increase the thermal inertia or capacity of the system, and is light enough to use on-board a vehicle. In contrast, the LFE flowmeter disclosed by Weigand is used with an engine mounted on a test stand where weight, thermal inertia, and preheating of the flowmeter are apparently not considerations (Col. 7, ll. 48-59). It would clearly not be practical for a vehicular application to require heating of the flow element to 150 °C prior to starting the engine as taught by Weigand to avoid formation of condensation.

As such, with respect to claims 1, 20, 22, 23, and 32, Weigand does not disclose or suggest measuring a pressure difference upstream and downstream of a screen as disclosed and claimed by Applicants. With respect to claims 12 and 15, Weigand does not disclose or suggest a flow restricting element (or screen) extending substantially entirely across a cross-sectional area of the tube.

With respect to claim 14, the Examiner states that Weigand is deemed to disclose a screen having about six strands per inch in a generally rectangular array as disclosed and claimed. Applicants respectfully disagree. Even if the LFE disclosed by Weigand could be considered a screen, which it is not, Weigand does not suggest sizing of the open area to reduce condensation as taught by Applicants and does not disclose an LFE having about six "strands" (or cells) per inch as the Examiner contends. Rather, Weigand discloses that each parallel tube 20 of the capillary section of the LFE is square in cross section with an open internal area of 0.05 by 0.05 inches (Col. 3, ll. 38-39), significantly smaller than the open area (0.1317 inches) of the six mesh screen taught by Applicants to reduce or eliminate condensation formation while minimizing added back pressure (See Paragraph [0028] for example). Applicants selection of a six mesh screen, or a screen with less than 10 strands per inch (Claim 21) provides advantages (acceptable backpressure while covering substantially entire cross-section, reduction or elimination of condensation, light weight) that are neither disclosed nor suggested by the LFE taught by Weigand. In contrast, Weigand teaches that LFE 18 is subject to condensation formation and requires a heating element 28 to preheat body 12 and LFE 18 before starting the engine to avoid condensation. As such, LFE 18 clearly does not have the necessary construction as taught by Applicants and claimed in claims 13, 14, and 21.

As described above, Applicants' disclosed and claimed screen and measuring a pressure drop across a screen is clearly patentably distinguishable from the LFE disclosed in Weigand '903. As such Applicants' claims 1, 12-21, 23-27, and 32 include features that are not anticipated by Weigand '903 and Applicants respectfully request that the rejection under 35 USC §102(b) be reversed.

REJECTION UNDER 35 USC §103(a)

Does Weigand '903 Provide Any Suggestion, Teaching, or Motivation That Renders Applicants' Claimed Features Obvious?

Applicants invention as claimed in claims 4, 7, 8, and 35 are specific methods for real-time determination of exhaust gas flow based on formulas

developed by Applicants for use with the differential pressure measured across a screen or similar flow restricting element. Applicants describe particular applications and advantages/disadvantages for the various claimed formulas, such as being more susceptible to instrument-to-instrument variation [Para 41], having good correlation with flow calculated by the engine controller [Para 46], or being easier to calibrate in the field [Para 47-51], that are not recognized by Weigand '903. The Examiner has not cited any support in Weigand '903 or otherwise for modifying the formulas disclosed in Weigand '903 for use with an LFE to arrive at Applicants' claimed method for use with a screen. The Examiner's position that these claims "merely set forth a mathematical manipulation to determine the exhaust flow which would be within the realm of one having ordinary skill in the art" is insufficient to support the rejection. Because Weigand '903 is directed to determining exhaust flow based on a pressure difference across a capillary section of an LFE in a test/laboratory environment, there is no teaching, suggestion, or motivation to modify the calculations disclosed by Weigand to those disclosed and claimed by Applicants.

Similarly, Weigand '903 fails to provide any teaching, suggestion, or motivation to provide the features of Applicants' claims 22, 29, 30, or 31. For example, Weigand does not teach or suggest a stainless steel screen or flow restricting element as recited in Claim 22. The only material disclosed in Weigand for capillary section 18 is ceramic. Weigand is not "silent" as to the material for LFE 18 as stated by the Examiner, but rather suggests that ceramic was selected because of its relatively unchanging properties over a wide range of temperatures. Likewise, Weigand does not teach or suggest the use of a condensation trap as claimed in Claims 29 and 30. Rather, Weigand teaches the use of an electric heater coil to eliminate condensation, which is undesirable for on-board or portable systems as claimed by Applicants. Weigand is directed to a test stand application, and does not recognize the problems associated with an on-vehicle application so there is no suggestion or motivation to provide anything other than a heater to reduce or prevent condensation. With respect to Claim 31, Weigand teaches ports for inserting probes to measure temperature and pressure, but does not teach any port for extracting a sample of the exhaust gas as claimed by Applicants.

For the reasons above, the rejection of dependent claims 4, 7, 8, 22, 29-31, and 35 under 35 USC §103(a) should be reversed.

SUMMARY

Applicants' invention as claimed in independent claims 1 and 32 requires a screen, which is not disclosed in Weigand '903 and the rejection for anticipation under 35 USC §102(b) should be reversed for this reason alone. Likewise, Applicants' claim 15 requires a flow restricting element that extends substantially entirely across the cross-sectional area of the tube/exhaust pipe. Weigand's capillary section does not extend substantially entirely across the cross-sectional area and so does not anticipate Claim 15 and the rejection under 35 USC §102(b) must be reversed.

The rejection under 35 USC §103(a) based on Weigand also fails for the reasons above. In addition, Weigand fails to recognize or appreciate the problems solved by Applicants' claimed invention and does not provide any teaching, suggestion, or motivation to modify the disclosed features such that the rejection under 35 USC §103(a) should be reversed.

(viii) CLAIMS APPENDIX

1. (Original) A method for real-time determination of exhaust gas flow through an exhaust pipe of a vehicle, the method comprising:
measuring a pressure difference upstream and downstream of a screen;
measuring exhaust gas temperature; and
determining the exhaust gas flow based on the pressure difference and the temperature.

2. (Original) The method of claim 1 wherein the step of determining the exhaust gas flow comprises determining the exhaust gas flow based on a square root of the quotient of the pressure difference and the temperature.

3. (Original) The method of claim 2 wherein the step of determining the exhaust gas flow further comprises:
determining a constant based on known flows, known temperatures, and a measured pressure difference; and
multiplying the constant by the square root.

4. (Original) The method of claim 1 wherein the step of determining the exhaust gas flow comprises determining the exhaust gas flow according to:
$$\text{Flow} = K * (\text{pressure difference})^x * (\text{temperature})^y$$
where "K" represents a constant.

5. (Original) The method of claim 4 further comprising:
measuring the pressure difference for a plurality of known flows and a constant temperature; and
determining slope of the logarithm of the known flows as a function of the logarithm of the pressure differences to determine a value for the exponent "x".

6. (Original) The method of claim 4 further comprising:
measuring the pressure difference for a plurality of known temperatures and a constant flow; and

determining slope of the logarithm of the quotient of the flow and the pressure difference as a function of the logarithm of the temperature for each temperature; and

averaging the slopes for each temperature to determine a value for the exponent "y".

7. (Original) The method of claim 4 wherein a value for "K" is empirically determined.

8. (Original) The method of claim 1 wherein the step of determining the exhaust gas flow comprises determining the exhaust gas flow according to: differential pressure = A * flow + B*flow² where "A" and "B" are empirically determined constants.

9. (Original) The method of claim 8 wherein "A" and "B" are determined during calibration by measuring differential pressures across the screen during a low flow condition and a high flow condition, respectively, at a reference exhaust gas temperature and ambient pressure.

10. (Original) The method of claim 8 wherein the step of determining the exhaust gas flow further comprises adjusting the real-time measured pressure difference based on the measured exhaust gas temperature, the reference exhaust gas temperature, measured ambient pressure, and the reference ambient pressure.

11. (Original) The method of claim 10 wherein the real-time measured pressure difference is adjusted by multiplying by a factor "K", where: $K = (T_{REF}/T_{actual})^{-2Y} (P_{Ambient}/P_{REF})$ and "Y" is determined based on a relationship of differential pressure as a function of temperature for the low flow and high flow conditions.

12. (Original) The method of claim 1 wherein the screen covers substantially the entire area of the exhaust pipe.

13. (Original) The method of claim 1 wherein the screen mesh is selected to generate a measurable pressure difference while minimizing back pressure and formation of condensation on the screen.

14. (Original) The method of claim 1 wherein the screen includes about six strands per inch arranged in a generally rectangular array that extends across the exhaust pipe.

15. (Previously Presented) A portable system for determining exhaust gas flow of a vehicle, the system comprising:

a tube adapted for placement on an exhaust pipe of the vehicle, the tube including a flow restricting element extending substantially entirely across a cross-sectional area of the tube, a first port disposed upstream of the flow restricting element for measuring a first pressure, and a second port disposed downstream of the flow restricting element for measuring a second pressure; and

a device in communication with the tube for determining the exhaust gas flow based on a difference between the first and second pressures.

16. (Original) The system of claim 15 wherein the tube further comprises a third port for measuring temperature of exhaust gas flowing through the tube.

17. (Original) The system of claim 16 further comprising a thermocouple extending through the third port and in communication with the device to measure temperature of the exhaust gas flowing through the tube.

18. (Original) The system of claim 16 wherein the device determines the exhaust gas flow based on a difference between the first and second pressures and the temperature of the exhaust gas.

19. (Original) The system of claim 15 wherein the device includes at least one differential pressure transducer to generate a signal based on the difference between the first and second pressures.

20. (Original) The system of claim 15 wherein the flow restricting element comprises a screen.

21. (Original) The system of claim 20 wherein the screen comprises a plurality of strands arranged in a generally square array with less than ten strands per inch.

22. (Original) The system of claim 20 wherein the screen is made of stainless steel.

23. (Original) The system of claim 15 wherein the flow restricting element comprises a disk having regularly spaced openings.

24. (Original) The system of claim 23 wherein the openings comprise between 60% and 65% of the cross-sectional area of the disk.

25. (Original) The system of claim 15 wherein the device includes a microprocessor to determine the exhaust gas flow.

26. (Original) The system of claim 15 wherein the tube is straight to reduce added back pressure.

27. (Original) The system of claim 15 wherein the flow restricting element includes sufficient spaces to limit any increase in back pressure to less than six percent.

28. (Original) The system of claim 15 wherein the device comprises:
a first differential pressure transducer generating a first signal based on the difference between the first and second pressures corresponding to a first range of exhaust flows; and

a second differential pressure transducer generating a second signal based on the difference between the first and second pressures corresponding to a second range of exhaust flows.

29. (Original) The system of claim 15 further comprising:

a condensation trap positioned upstream relative to the flow restricting element.

30. (Original) The system of claim 29 wherein the condensation trap comprises:

a conical screen having an apex pointing upstream; and

a baffle disposed downstream of the conical stream.

31. (Original) The system of claim 15 wherein the tube further comprises a fourth port for extracting samples of exhaust gas passing through the tube.

32. (Original) A portable exhaust gas flow sensor for real-time on-board measurement of exhaust gas flow from a vehicle, the sensor comprising:

a straight tube for connecting to an exhaust pipe of the vehicle, the tube including an interior screen to generate a pressure drop as exhaust gas flows across the screen, an upstream port for measuring pressure upstream of the screen, a downstream port for measuring pressure downstream of the screen, and a thermocouple port for measuring exhaust gas temperature;

a differential pressure transducer in communication with the upstream and downstream ports for generating a signal based on a pressure difference between the upstream and downstream ports;

a thermocouple in communication with the thermocouple port for generating a signal based on temperature of exhaust gas flowing through the straight tube; and

a processor for receiving the signals from the differential pressure transducer and the thermocouple and determining exhaust gas flow based on the received signals.

33. (Original) The sensor of claim 32 further comprising:

a second differential pressure transducer in communication with the upstream and downstream ports for generating a second differential pressure signal based on the pressure difference between the upstream and downstream ports, wherein the first differential pressure signal corresponds to a first range of exhaust gas flows and the second differential pressure signal corresponds to a second range of exhaust gas flows.

34. (Original) The sensor of claim 33 wherein the processor selects one of the first and second differential pressure signals to use in determining the exhaust gas flow.

35. (Original) The sensor of claim 32 wherein the processor determines exhaust gas flow according to:

$$\text{exhaust gas flow} = K\Delta P^x T^y$$

where ΔP represents the differential pressure, T represents the temperature of the exhaust gas, and K , x , and y are empirically determined.

(ix) EVIDENCE APPENDIX

Applicants are not relying on any evidence not already made of record.
Applicants rely on the specification and drawings as filed and the prior art cited
by the Examiner (US 5,837,903)

(x) RELATED PROCEEDINGS APPENDIX

Applicants are not aware of any related proceedings as stated above.

Respectfully submitted:

A handwritten signature in black ink, appearing to read "David S. Bir", written over a horizontal line.

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